MODELING OF A MOTORCYCLE FOR COLLISION SIMULATION

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ABSTRACT

ISO13232 [1], which defines test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles, recommends 200 configurations of simulation calculations. Considering the diversity of configurations, the multi-body dynamics based software "MADYMO" (MAthematical DYnamic MOdel) rather than FEM based software was adopted in the present study as a basic simulation tool.

In this research, a proto-type test vehicle was selected as the motorcycle model, and a proto-type airbag system was used as an example of a protective device. To determine the impact characteristics of the motorcycle front structure and the contact characteristics between the motorcycle and the rider dummy, several component tests were performed. Prescribed motion simulations and a barrier test simulation were also carried out to validate the motorcycle model. As a result, this model was found to show good performance in simulating the motorcycle to dummy contact and the motorcycle to barrier impact.

INTRODUCTION

Numerical simulation of motorcycle-car collision is one of the most effective tools in motorcycle passive safety. It is not practical for real world collision tests to cover all of the various collision configurations of real world accidents, although conducting those tests is indispensable to develop rider protective devices. For example, ISO13232 specifies 200 configurations in which protective devices should be evaluated. Another remarkable feature of motorcycle-car accidents is that the rider is likely to experience secondary impact with the environment (such as the road) because of not being constrained to the motorcycle. This means that the analysis time to be considered is much longer than that in car-to-car collisions. Considering the diversity of collision configurations and the length of analysis time, the multi-body dynamics based software MADYMO rather than the more time consuming FEM software was adopted as a basic simulation tool.

The motorcycle model selected was a proto-type test vehicle. In MADYMO a simulation model generally consists of rigid bodies, joints and surfaces: a joint connects one rigid body to another, and a surface is attached to a rigid body to shape the model or to produce a contact force [2]. Our motorcycle model has 21 rigid bodies and the same number of joints. The surfaces used are 9 ellipsoids, 7 cylinders, 2 planes and 8 facet surfaces. The main contacting parts (such as front cowl and seat) are formed by facet surfaces to produce more precise contact force (see Figure 1.)

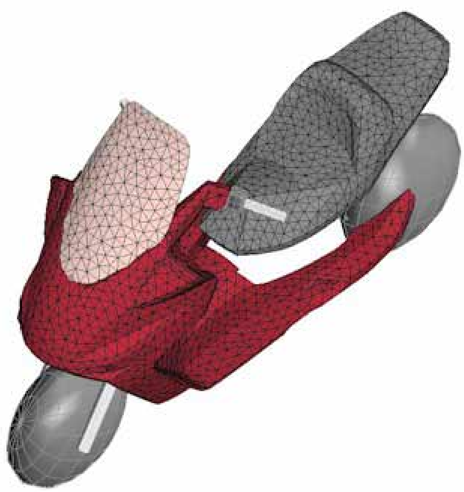


Figure 1. Motorcycle model.

A proto-type airbag system was used as an example of a protective device, though this research focuses on the process of modeling a motorcycle for collision simulation. This airbag system was modeled with an inflator system and an FEM model which has 2,200 membrane elements.

The rider dummy model used a modified Hybrid III standing model, since it had also been used in collision tests. Modification was performed mainly on joint stiffness, mass distribution and surfaces to conform to the real dummy or to improve contact characteristics of the dummy model.

To determine the impact characteristics of the motorcycle front structure and the contact characteristics between the motorcycle and the rider dummy, several component tests were performed. This paper describes some of the results of these tests and simulations. Besides the component tests, prescribed motion simulations and a barrier test simulation were carried out to validate the motorcycle model. The results of these simulations are also shown herein.

COMPONENT TEST

In the beginning of a motorcycle-car collision, the motorcycle front contacts the car and the rider dummy contacts the motorcycle parts (front cowl, handlebar etc.). Since the initial contact phenomena can affect all the kinematics throughout the collision accident, it is very important to determine the characteristics of these phenomena. For this reason the following component tests were carried out: front fork bending test, motorcycle front structure impact test, front cowl impact test, seat static loading test, handlebar bending test, seat-dummy friction load measurement, and the like.

The contact characteristics of the tire and rim of the front wheel were previously investigated and obtained [3]. A front fork bending test was performed to obtain the bending stiffness of the corresponding revolute joint. Figure 2 is a picture of motorcycle front structure impact test and Figure 3 shows the result of this test, as an example of these tests. Figures 4 and 5 show a picture and the result of a front cowl impact test. The contact characteristics obtained by smoothing the force vs. displacement curves in Figures 3 and 5 were directly introduced into the MADYMO motorcycle model.

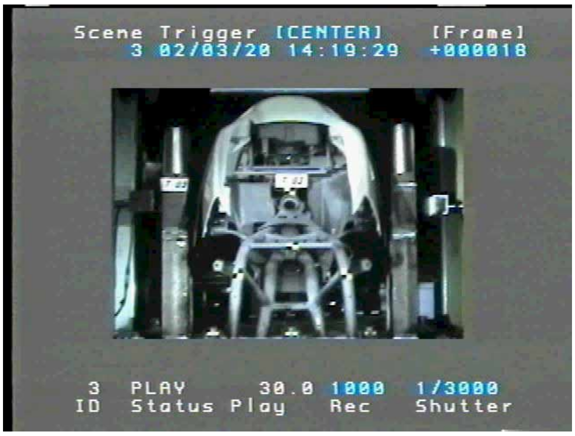


Figure 2. M/C front structure impact test.

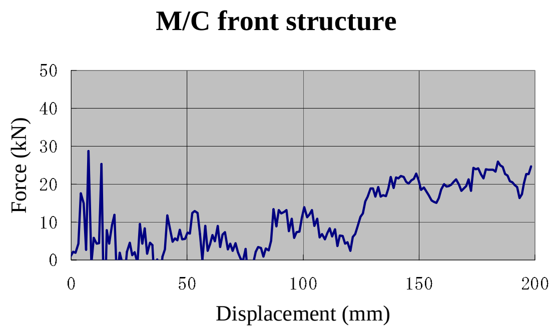


Figure 3. Force vs. displacement of M/C front.

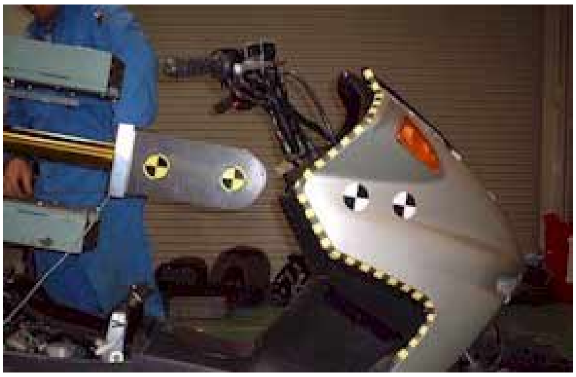


Figure 4. Front cowl impact test.

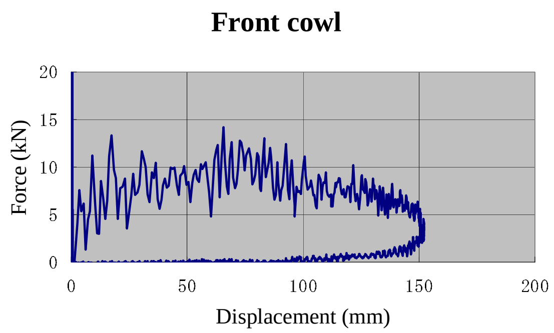


Figure 5. Force vs. displacement of front cowl.

In the seat loading test and handlebar bending test, MADYMO models were made to simulate the test conditions. Then, seat loading characteristics and handlebar bending stiffness of the corresponding joint were obtained. Figure 6 shows pictures of a seat loading test and its simulation model. A comparison between test and simulation results is shown in Figure 7. Similarly, Figures 8 and 9 show handlebar bending test. In Figures 7 and 9 the darker green lines indicate the test results and the lighter green lines the simulation results. By applying suitable properties, the two curves in Figures 7 and 9 show good coincidence. Those properties were introduced into the MADYMO motorcycle model.

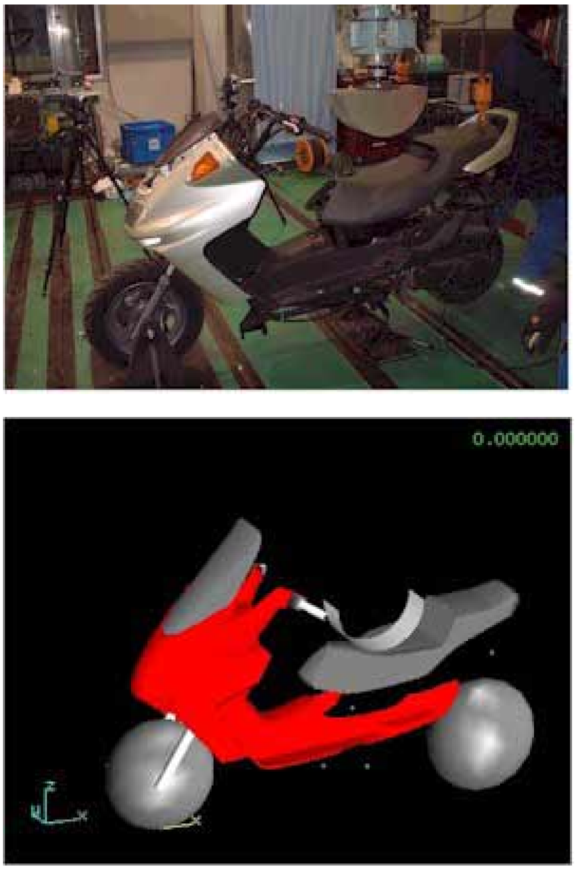


Figure 6. Seat loading test.

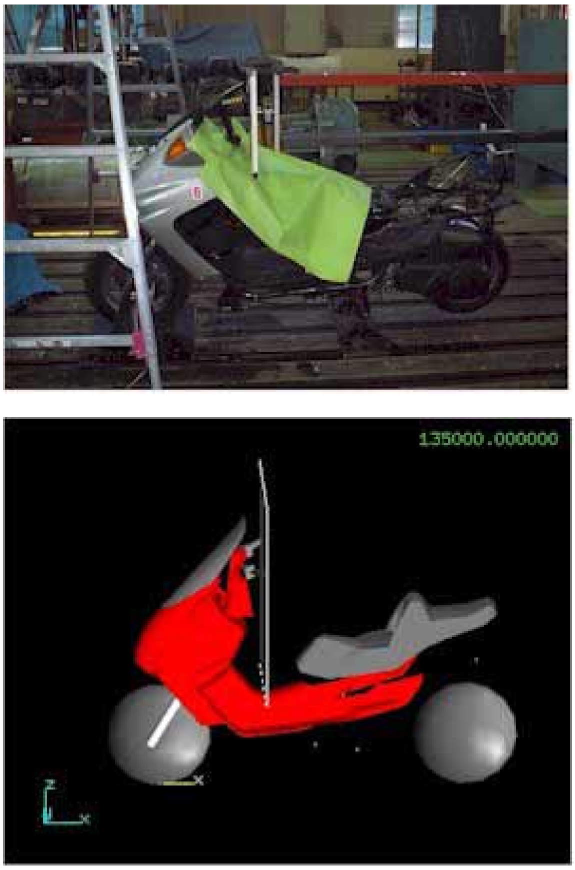


Figure 8. Handlebar bending test.

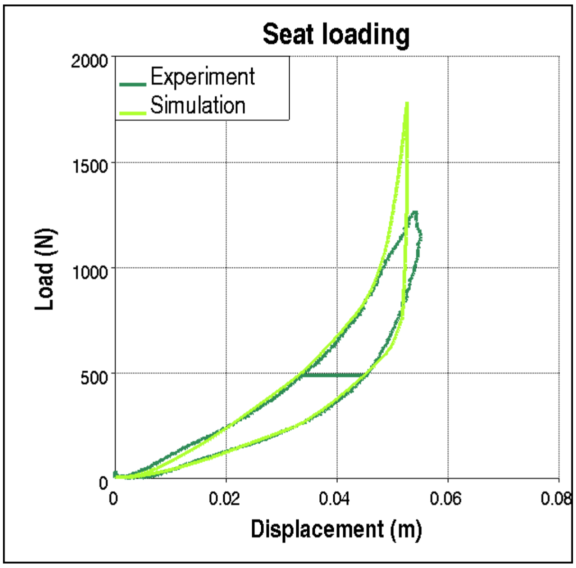


Figure 7. Comparison of seat loading.

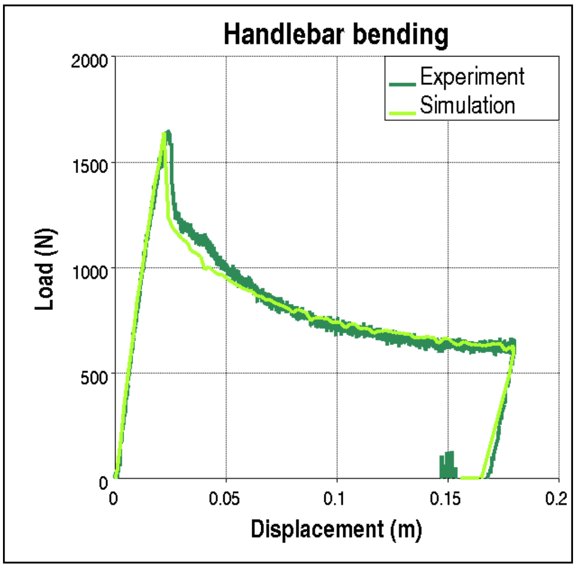
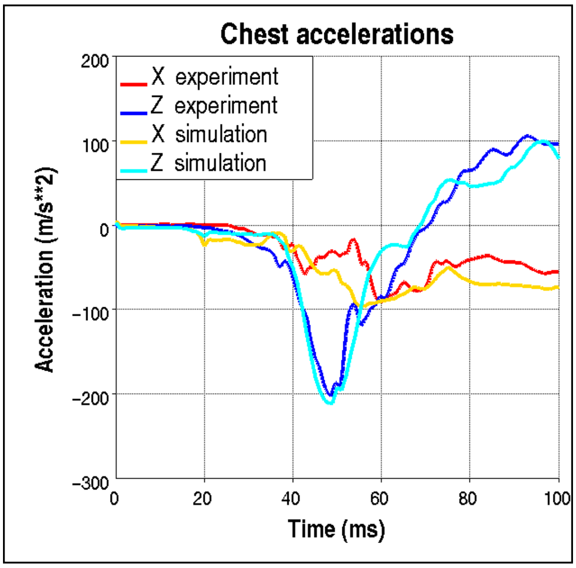


Figure 9. Comparison of handlebar bending.

PRESCRIBED MOTION SIMULATIONS

To validate the motorcycle model, prescribed motion simulations were carried out. In a prescribed motion simulation, a motorcycle model is given motion data, which can be obtained by analyzing test video data, and the model is moved the same way as in the real test. Dummy data such as chest accelerations obtained by this simulation can then be compared with the test results.



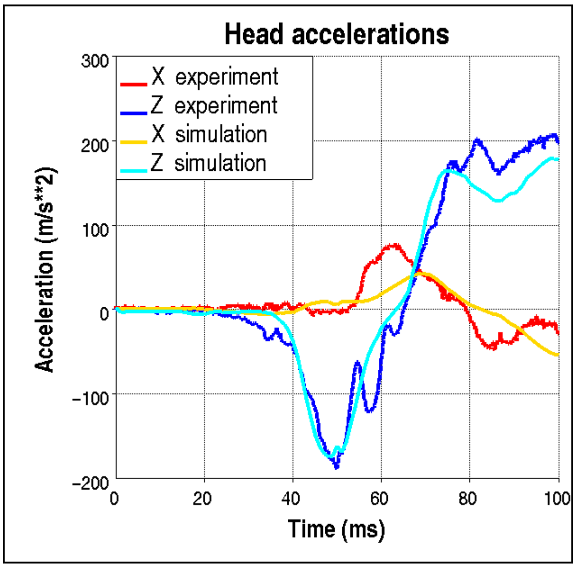


Figure 10. Validation results without airbag.

Figure 10 shows the validation results from a comparison of the rider dummy data (chest accelerations and head accelerations) between a test and simulation in the case of a 413-0/30 configuration without an airbag system. In this configuration, a 30 mph motorcycle collides with the side of a stationary car at a right angle. In Figure 10, red lines indicate x-direction test data, yellow lines x-direction simulation results, dark blue lines z-direction test data and light blue lines z-direction simulation results. The x-direction means the forward-backward direction, and the z-direction the downward-upward direction. (Hereinafter the same color is used.) In addition, Figure 11 shows a kinematic comparison from 0 msec to 100 msec at time intervals of 20 msec.

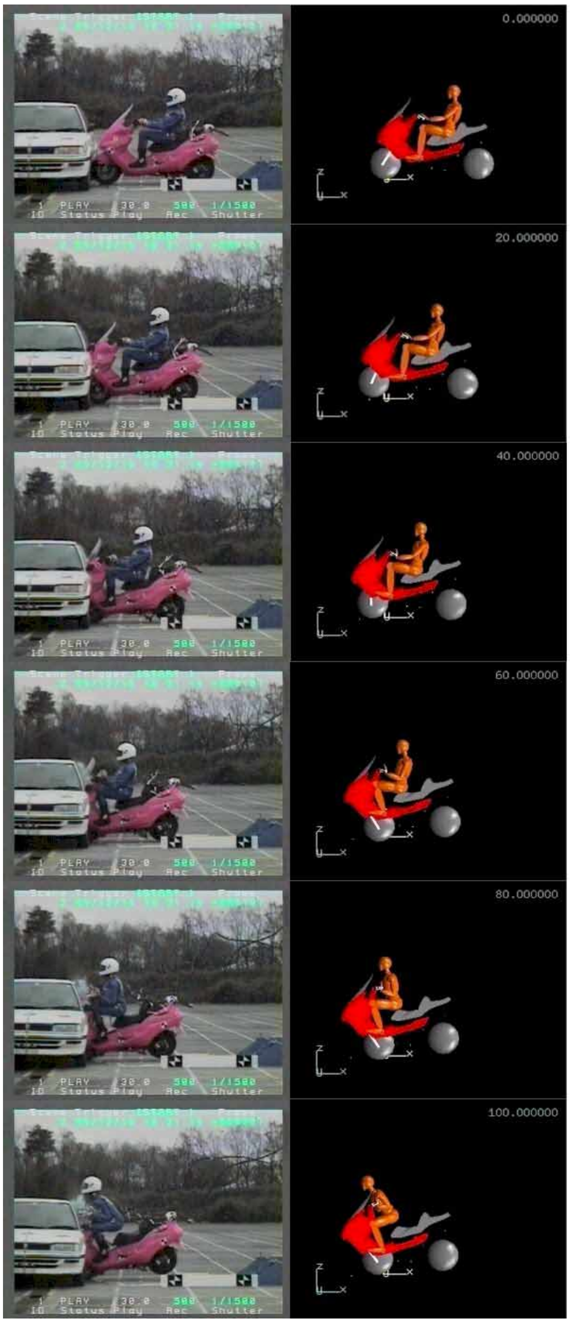


Figure 11. Kinematic comparison without airbag.

These graphs and pictures show qualitatively good coincidence.

In the same way, the validation results and kinematic comparison for the same configuration with the airbag system are shown in Figures 12, 13.

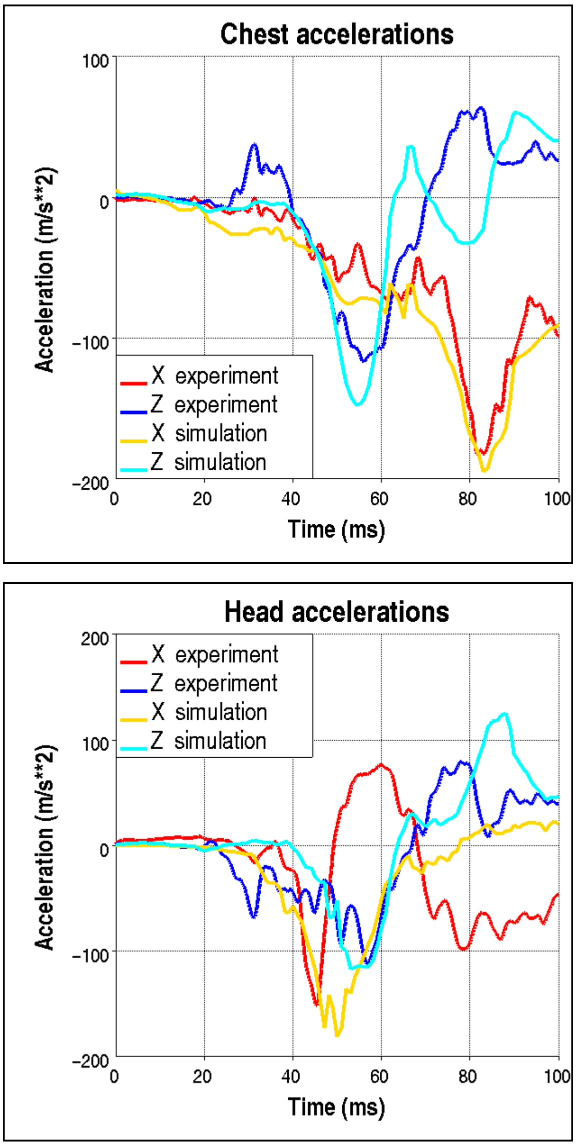


Figure 12. Validation results with airbag.

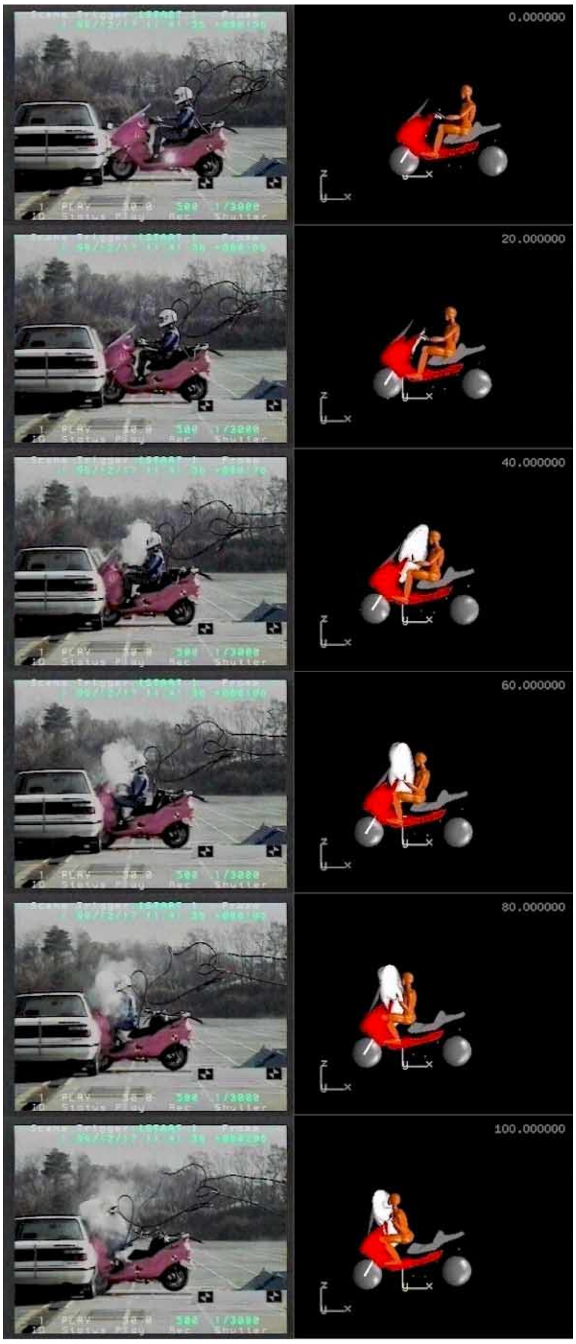


Figure 13. Kinematic comparison with airbag.

In this case, although dummy kinematics shows good coincidence, a difference between test results and simulation results is seen, especially in x-direction head acceleration. The difference in deployment process is considered to be the reason for this discrepancy. The airbag model has not been able to reproduce the deployment process precisely, so we consider that improvement of the airbag model and its deployment process is necessary. We are now attempting to make such improvements.

BARRIER TEST AND ITS SIMULATION

In addition to the prescribed motion simulations, a barrier test and its simulation were performed to validate the motorcycle model. In this test, a 30 mph motorcycle collided with rigid wall at a right angle. The barrier force and motorcycle accelerations were measured.

Figure 14 shows the validation results from a comparison of the barrier force and the motorcycle accelerations (the center of gravity, on the front fork) between the test and simulation.

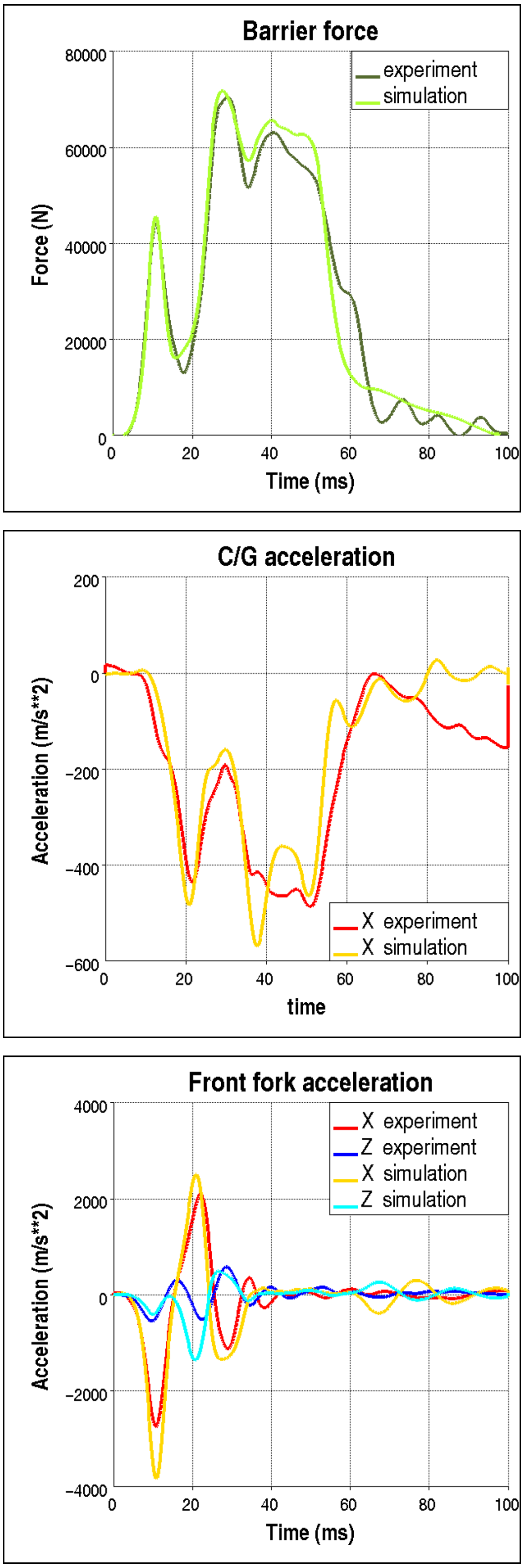


Figure 14. Validation results of barrier test.

The motorcycle kinematics is shown in Figure 15 from 0 msec to 100 msec at time intervals of 20 msec.

Figure 15. Kinematic comparison of barrier test.

In Figure 14, simulation results are qualitatively in good agreement with test results. Figure 15 also shows good coincidence in motorcycle kinematics, except for the intrusion of the motorcycle front into the barrier, which is inevitable for a rigid body model.

CONCLUSIONS

A motorcycle model of the first stage for collision simulation has been developed. Several component tests and their simulations for the handlebar and the seat were carried out and important characteristics for collision simulation were determined. Then, by means of prescribed motion simulation, validation for the contact phenomena between motorcycle and dummy was performed. In addition, validation for the impact phenomena between motorcycle and barrier was done through a barrier test simulation.

As a result of these procedures, this model was found to show good performance in simulating the motorcycle to dummy contact and the motorcycle to barrier impact, but not the dummy to airbag contact. To improve the dummy to airbag contact simulation, reproducing the airbag deployment process more accurately is considered to be necessary.

We are now on the way to modeling a motorcycle for collision simulation and accomplishing full simulation for motorcycle to car collisions. We will continue to try to improve the motorcycle model.

REFERENCES

(1) International Standard ISO 13232: 1996(E). Motorcycles – Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles, Parts 1 to 8, International Standards Organizations, Geneva, December 1996.

(2) MADYMO Theory Manual Version 6.0, TNO Automotive, April 2001.

(3) Fujii S., Crash Analysis of Motorcycle Tire, JSAE Autumn Convention, 2002.